Indian Journal of Traditional Knowledge
Vol 18(4), October 2019, pp 793-799

Weathered basalt application for management of Vertisols: A traditional knowledge of groundnut (*Arachis hypogaea*) growers of Gujarat, India

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Received 20 November 2018; revised 08 August 2019

Gujarat tops with 27.87% of total groundnut production. The basaltic shrink-swell soils are generally evaluated as unsuitable for groundnut production in Saurtashtra region of Gujarat. They have untapped source of traditional knowledge for managing heavy shrink-swell soils of basaltic terrain. Groundnut growers of the region are applying weathered basalt (WB, Vēraḍēḍa bēsāḷtanuṁ in Gujarati) in pure form which is naturally available or sometimes treated by mixing the farmyard manures (FYM) or groundnut husk, and/or fortified with nitrogenous and phosphatic fertilizers. A study was planned to find out the reason for higher production of groundnut with the application of WB before sowing the seed. For this study the farmers were divided in to 05 groups on the basis of forms and combinations of WB application in groundnut fields. The participatory approaches and personal interviews were combined to collect the data from 25 farmers of each group. After interviewing the farmers, we came to know that this practice is being followed since 40 years. The study revealed that the practice significantly reduces the contracting and expanding phenomenon in black Vertisols and improve physico-chemical properties of soils like hydraulic characteristics (infiltration, permeability, percolation and drainage), aeration, bulk density, porosity, thermal conductivity and also improve availability of secondary (Ca, Mg & S) and micronutrients (Fe, Mn, Zn & Cu). The present study forms the basis for upgrading the traditional management packages for sustainable groundnut production in black soil region of India.

Keywords: Black soil region, Groundnut, Management of vertisols, Traditional knowledge, Weathered basalt

IPC Code: Int. Cl.[19]: D01F 4/06, A01B 35/00, A01C 1/06, A61K 36/00

Local knowledge about the type and suitability of soils for crop production[1] helps farmers to reduce environmental risks and minimize crop failures and thus enhance the livelihoods[2]. Local knowledge related to agriculture can be defined as indigenous skills, knowledge and technology accumulated by local people derived from their direct interaction with environment[3]. As per the soil site-suitability criteria groundnut can be best cultivated in loamy soils[4] but the farmers of western Gujarat getting very good yield in fine to very fine textured soils[5] using the local soil management knowledge. Local soil knowledge can be defined as "the knowledge of soil properties and management possessed by people living in a particular environment for some period of time"[6]. Farmers consider their location specific crop systems to be ecologically sustainable, economically viable and culturally acceptable[7]. The locally available weathered basalt (*murrum*) is utilized among the peoples of western Gujarat in fine textured soils under groundnut crop. The major groundnut growing soils of Gujarat are moderately deep, medium to fine textured black in colour developed over weathered basalt[8]. Cultivation of groundnut on these soils requires a lot of experience and management skill. An improper management at any stage may lead to total failure of the crop[8]. Despite this limitation groundnut is grown as main cash crop in this area. Farmers of a particular locality play a key role in managing the production limiting factor through their local traditional knowledge interventions. Few studies indicated that resource-poor farmers, by applying traditional practices of natural resource conservation, outperform their rich counterparts[9,10]. Sometimes the surface stoniness is proved as boon for cotton growing soils of western Maharashtra and

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Marathwada[11]. Because stoniness roughens the surface and thus protect it from the direct impact of rain drops and counteracts runoff and thereby reduce the erosive velocity[8,11]. Stoniness has further significance in reducing the evapo-transpiration and thus enhances the length of growing period. Organic manures have been reported by several workers to play a crucial role in improving soil physical, chemical and biological properties[6] but their importance in modern input-intensive crop production technologies needs to be further evaluated, especially in groundnut based cropping systems. However, the application of weathered basalt requires knowledge of soil mineral properties and its consequences when large-scale application will likely lead to an alteration of soil chemistry and consequences for adjacent agricultural fields remain to be assessed in Saurashtra region.

Methodology

Study area

The study was conducted in Pata Meghpar village of Jamnagar district Gujarat situated between 22^0 13" 12' & 22^0 16" 06' N latitudes and 70^0 29" 07' & 70^0 32" 56'E longitudes (Fig. 1). The village Pata Meghpar comes under administrative boundary of Kalavad Taluka and located on eastern boundary of Jamnagar district and western boundary of Rajkot district. The Und river crosses the village Pata Meghpar. It is a part of peninsular region; the physiography of the area is partly hilly and partly plain[12]. Geology of the area is Deccan trap, the basic lava flow. The rocks are basaltic in composition and spread over wide areas in the form of horizontal sheets and give rise to a relief typical of the Deccan trap topography. Basalt is a very common dark-colored volcanic rock composed of calcic plagioclase[12]. In this region the basalt contains olivine, quartz, hornblende, nepheline, orthopyroxene, etc. It is composed of mineral grains which are mostly indistinguishable to the naked eye. Black color is given to basalt by pyroxene and magnetite. Both of them contain iron and this is the reason of their black colour. Basalt is a major rock type that occurs in virtually every tectonic setting. Crushed basalt is used for road base, concrete aggregate, building construction and railroad ballast in the region. It is the original constituent of the crust from which almost all other rock types have evolved[10]. The study area experiences tropical semi-arid climate characterized by hot summer and intense winter with a mean annual rainfall 739 mm[12]. The total production of groundnut in Gujarat was estimated at 30,54,671 million tonnes with an average yield of 1,879 kg/ha in year 2017[14]. Groundnut is an important oilseed crop of Saurashtra region (Gujarat) which accounts for about 85% of the total area confined to the 05 districts *viz.* Junagarh, Rajkot, Amreli, Bhavnagar and Jamnagar[14]. About 90% of the groundnut soils in the state are medium black in colour. Taxonomically, these soils are either Vertic Haplustepts or Typic Haplusterts[15].

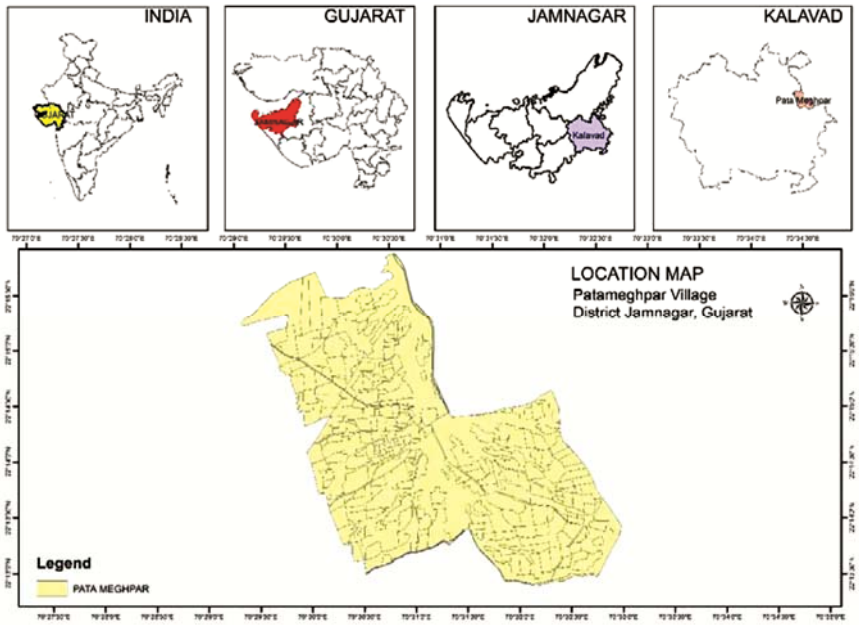

Fig. 1 — Location map of Pata Meghpar village

Research methodology

A detailed soil survey programme was executed in village Pata Meghpar of Jamnagar district in Saurashtra region for large scale soil mapping for land use planning[15]. We planned a study to find out the reason of higher production with the application of WB. For this study the farmers were divided in 05 groups on the basis of forms and combinations of WB application in groundnut fields. The participatory approaches and personal interviews were combined to collect the data from 25 farmers, i.e., 05 farmers from each group. The farmers used to grow groundnut variety 'Girnar 2'. It was a bold seeded variety which respond well to applied fertilizers and gave yield up to 3800 kg to 4000 kg/ hectare when sown in pre-monsoon season or in the month of June. In general, they followed the recommended package of practices[13] The depth of soils in groundnut fields ranged from 50 cm to 100 cm underneath weathered basalt. Lot of basaltic material was available within the village from dug wells or from areas exposed by Und river. These were collected and dumped over the field in straight lines. Heaps of weathered basalt were collected from the source and mixed thoroughly with farm yard manures (FYM) and kept for a period of 30 days for proper decomposition. Sometimes they fortified this mixture with urea and single super phosphate (SSP). There were 05 different kinds of basalt based input management for groundnut production.

1 Control, without application of weathered basalt (WB)
2 Only weathered basalt was applied
3 Only farm yard manure (FYM) was applied
4 FYM and weathered basalt both were applied
5 FYM and weathered basalt both were applied after fortification with urea and single super phosphate (SSP)

Soil analytical methods

The horizon-wise soil samples from representative pedons were air-dried, sieved to pass a mesh of aperture 2-mm for generalized soil properties and the <2-mm fractions ground to a fine powder (<63 μm) for OC determination. The particle-size distribution was determined by the International Pipette method[16]. The pH, electrical conductivity, exchangeable bases, exchangeable sodium percentage and cation exchange capacity (CEC) were determined by standard methods[17,18]. For the determination of OC, the modified Walkley and Black[19] rapid titration procedure was followed. Calcium carbonate was determined by acid neutralization method[20]. Available water capacity (AWC) was determined using the expression suggested by Gardner[21] and later modified by Coughlan[22].

Results and discussion

Physico-chemical characteristics of soils

The basaltic shrink-swell soils on nearly level plain, are moderately deep to deep, moderately well drained, dark grayish brown to very dark grayish brown, clay loam in the surface but changed to very dark gray, clayey in sub surface (Table 1). These soils were cultivated for double crops; groundnut/cotton during the *Kharif* season and wheat/gram/ fennel/cumin during *Rabi* season. These soils were classified up to family level as fine, mixed hyperthermic family Typic/Leptic Haplusterts and Vertic Haplustepts in subgroup of Vertisols. The physico-chemical properties of three representative pedons has been given in Table 1 & Table 2. Soils were slightly alkaline (pedon 2 & 3; pH 8.1 to 8.5) to moderately alkaline (pedon 1; pH 8.5- 8.8), non-saline (electrical conductivity <1.1 dSm^{-1}), calcareous ($CaCO_3$; 9.8% to 17.4%) and medium in organic carbon content (Table 2). High cation exchange capacity (48.1 to 66.4 cmol/kg).

Grouping of groundnut growers:

The groundnut growers were grouped in 05 categories *viz.* T1: Control; without application of WB, T2: WB, T3: FYM, T4: WB+FYM (1:1 by volume), and T5: WB+FYM+ fortification with urea and SSP. The impact of these treatments on groundnut production was observed. There is an increment in growth, development and yield of groundnut under different management systems (personal observation during field survey). The groundnut yield trend was observed in order of T1<T3<T2<T4<T5. Data showed that yield was almost double under treatment T5 as compared to control (T1) (Table 3). The opinions of farmers behind the applying of weathered basalt in their groundnut field were more or less same in this area. The pre-sowing application of weathered basalt to the soil increases the groundnut yield. Farmers collect the WB from soil areas exposed by Und river or dug wells manually or using J.C. Bamford Excavators (Photo 1). Since groundnut is sown on ridges in straight lines (Photo 2 and Photo 3), the application of weathered basalt keeps the furrows intact. Many farmers, however, believe that weathered basalt acts as a good source of nutrients for groundnut.

Table 1 — Physical properties of soils

Horizon	Depth (cm)	Particle size class and diameter in mm								Water retention (%)		
		Total (%)			Sand fractions (%)							
		Sand	Silt	Clay	Very coarse	Coarse	Medium	Fine	Very fine	-33	-1500	AWC
		2.0-0.05	0.05-0.002	<0.002	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.10	0.1-0.05	kPa	kPa	
Pedon 1:Fine, smectitic (cal), hyperthermic, Vertic Haplustepts												
Ap	0-15	35.1	27.2	37.7	7.0	6.7	7.0	5.2	9.2	34.0	20.0	14
Bss1	15-30	20.6	28.4	51.0	5.5	2.5	2.2	3.0	7.4	39.7	28.8	10.9
Bw1	30-55	16.7	40.2	43.1	2.4	2.3	2.1	2.9	7.0	40.6	31.0	9.6
Bw2	55-70	14.7	39.7	45.7	2.3	2.3	2.0	2.2	5.9	39.9	30.5	9.4
Pedon 2:Fine, smectitic (cal), hyperthermic, Leptic Haplusterts												
Ap	0-15	16.7	32.1	51.3	0.8	1.8	3.7	3.3	7.1	43.4	30.0	13.4
Bss1	15-40	20.4	27.2	52.4	2.3	2.1	3.9	3.6	8.5	39.8	29.2	10.6
Bss2	40-65	17.4	27.2	55.4	2.1	1.9	2.4	3.0	8.0	41.4	31.3	10.1
Bss3	65-75	17.3	41.6	41.1	3.3	3.3	3.0	2.6	5.1	41.6	30.3	11.3
Pedon 3:Fine, smectitic (cal), hyperthermic, Typic Haplusterts												
Ap	0-15	25.0	27.7	47.4	5.7	3.5	3.5	3.7	8.5	36.7	24.4	12.3
Bss1	15-38	15.6	46.9	37.6	1.2	1.0	2.0	3.2	8.2	35.6	28.6	7.0
Bss2	38-65	15.0	41.3	43.8	3.7	1.4	1.3	2.1	6.4	41.6	31.5	10.1
Bss3	65-85	18.7	30.6	50.7	5.2	2.1	2.0	2.2	7.3	41.9	31.9	10.0
Bss4	85-105	24.0	34.5	41.5	3.5	3.2	5.3	4.3	7.7	38.5	24.9	13.6

Pedon-A pedon is the smallest unit of land surface that can be used to study the characteristic soil profile of a landscape.

Fine-It is family class of sandy clay, clay or silty clay textural classes with 41 to <60 percent clay fraction.

Hyperthermic- The mean annual soil temperature is 22°C or higher, and the difference between mean summer and mean winter soil temperatures is more than 5°C either at a depth of 50 cm from the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower.

Vertic/Leptic/Typic-Name of great group in soil taxonomy.

Hplusterts-It is a great group of Usterts suborder and Vertisols soil order as per the Key to soil taxonomy.

Table 2 — Chemical characteristics of soils

Horizon	Depth (cm)	pH (H_2O)	EC (dSm^{-1})	Org. C	$CaCO_3$	Exchangeable Cations				CEC	ESP %
						Ca	Mg	Na	K		
		-----1:2.5----		-------%-------		----------cmol (p^+) kg^{-1}---------					
Pedon 1:Fine, smectitic (cal), hyperthermic, Vertic Haplustepts											
Ap	0-15	8.6	0.4	0.7	14.4	32.2	12.2	2.5	0.1	51.2	5.3
Bss1	15-30	8.5	0.4	0.6	11.9	40.8	13.5	2.7	0.1	60.4	4.7
Bw1	30-55	8.7	0.4	0.6	11.2	43.2	12.6	3.5	0.1	63.1	5.9
Bw2	55-70	8.8	0.4	0.6	17.4	44.5	7.8	3.4	0.1	57.6	6.1
Pedon 2:Fine, smectitic (cal), hyperthermic, Leptic Haplusterts											
Ap	0-15	8.1	0.9	0.8	9.8	40.8	16.7	1.7	0.2	62.8	2.9
Bss1	15-40	8.2	0.7	0.7	11.5	41.6	14.7	2.0	0.2	61.6	3.4
Bss2	40-65	8.2	0.7	0.6	12.1	40.8	15.1	2.3	0.2	61.7	3.9
Bss3	65-75	8.3	0.5	0.7	16.8	36.7	16.7	2.0	0.2	58.6	3.6
Pedon 3:Fine, smectitic (cal), hyperthermic, Typic Haplusterts											
Ap	0-15	8.4	1.1	0.7	11.9	34.7	19.2	2.3	0.3	58.4	4.1
Bss1	15-38	8.5	0.7	0.7	11.9	42.0	15.5	2.5	0.2	63.2	4.2
Bss2	38-65	8.2	0.6	0.6	12.1	43.7	14.7	2.7	0.2	64.8	4.4
Bss3	65-85	8.3	0.6	0.6	15.7	44.2	16.4	2.1	0.1	66.4	3.3
Bss4	85-105	8.5	0.6	0.4	23.6	31.4	12.6	1.8	0.1	48.1	3.9

Table 3 — Yield of groundnut under different treatments

Treatments	Average yield (kg/ha)*	Per cent increase over control
T1: Control, without application of WB	1210	-
T2: weathered basalt (WB)	1850	53
T3: FYM	1840	52
T4: WB+FYM (1:1 by volume)	2150	78
T5: WB + FYM+ fortification with urea & SSP	2260	87

*Farmers data (average yield of 5 farmers of each treatment and calculated the yield on per hectare basis)

Photo 1 — Famers digging weathered basalt from basin of Und river of Pata Meghpar village

Photo 2 — Famers spread weathered basalt in straight lines in field

Photo 3 — Groundnut crop grown by farmers in lines treated with weathered basalt

Science involved in traditional knowledge

It is a well known fact that groundnut can be grown best in friable, sandy loam type of soil with high level of calcium content and a moderate amount of organic matter[4]. Presence of low amount of calcium ions and organic matter in fine textured black soils impaired the other important soil properties for the best growth of groundnut. Black soils are moderately well drained, dark colored, firm, clay loam to clay with poor organic matter content. These soils have high shrinking and swelling characteristics. Major problems associated with these soils lies in their physical characteristics which affects germination, *pegging* and pod development[8]. In such condition, application of any material (natural or synthetic) which can improve the physical characteristics of soil is likely to give better results. Such materials are referred to as 'soil conditioners'. Weathered basalt is generally gravelly loam to gravelly clay loam in texture. Application of this material helps to bring the soil in good structural condition. It improves soil aeration since pore spaces are increased. Its application also brings the soil in good tilth since bulk density of soil in the plough layer decreases which subsequently favours the development of healthy and bold pods. Besides, weathered basalt has the added advantage of high calcium content and groundnut is a calcium loving crop. Possibly, the improved physical condition of soil and adequate supply of calcium in fine textured soils play a favourable role in improving groundnut yield.

There was an old practice of England farmers to apply chalk in heavy soils and a dressing of FYM which increased mellowness of its tilth making it easy to work. Moreover, weathered basalt act as the stabilizer to maintain the furrow intact and does not allow the material to fall down from the ridge. This

also improves soil drainage which is essential for groundnut cultivation. The opinion of some of the workers[1] that farmers are applying it indiscriminately, although this practice is immediately paying farmers of Saurashtra region its other side effects namely, availability of plant nutrients (e.g., calcium induced nutrient deficiency), development of hard calcium carbonate layer in the sub-soil affect soil permeability and water retention The technique is being in practiced since last 40 years in fine to very fine black soils of Jamanagar and still giving good results. Weathered basalt is soft enough to transform in soil itself in few years by action of soil forming factors and tillage operations/interventions. This might not be enough to be problematic in Vertisols at any stage. This practice may be adopted all over the black soil region of India. However, it is cautioned that the weathered basalt might be high in concentration of chromium and nickel and their diffuse presence in the organo-mineral matrix of the samples that require further investigations in assessing their potential mobility from the authigenic phases(Marilyne Soubrand *et al.* 2005).

Conclusion

Pre-sowing application of weathered basalt; either in pure form or in combination of organic/inorganic amendments in swell-shrink soils helps to reduce the contraction and expansion phenomenon and improve the physical properties of soils. This practice not only improves the hydraulic characteristics, aeration, infiltration, permeability, porosity, thermal conductance of soils but also improves availability of secondary nutrients (Ca, Mg and S) and micronutrients for groundnut crop. Weathered basalt spread over the soil surface reduces runoff and protect the soils from erosion up to a certain extent. This practice may be followed among the groundnut growers of black soil region of Gujarat, Maharashtra and Andhra Pradesh for their sustainable groundnut production.

Acknowledgement

The authors acknowledge the support provided by Dr KN Akbari and Dr GS Sutaria, scientists in Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Rajkot and Gujarat.

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